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TESTS OF BLOWFLY BAITS AND REPELLENTS DURING 1926

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INTRODUCTION

The studies reported in the series of bulletins of which this is a part have been undertaken with the object of finding the most desirable substances which can be used to prevent the infestation of wounds on animals by the various species of flies that are attracted to the exposed flesh about such wounds.

Reports of the progress previous to 1926 in the investigations of materials that are attractive or repellent to the screw-worm fly, *Cochliomyia macellaria* Fab., and other blowflies have already been published.[2] The study of these materials was continued during the year 1926 at Uvalde and Dallas, Tex., and the results are reported in this bulletin.

[1] This work was done by R. C. Roark while connected with the Insecticide Laboratory, Bureau of Chemistry, C. C. McDonnell, in charge.

[2] BISHOPP, F. C., COOK, F. C., PARMAN, D. C., and LAAKE, E. W. PROGRESS REPORT OF INVESTIGATIONS RELATING TO REPELLENTS, ATTRACTANTS, AND LARVICIDES FOR THE SCREW-WORM AND OTHER FLIES. Jour. Econ. Ent. 16: 222-224. 1923.

——— ROARK, R. C., PARMAN, D. C., and LAAKE, E. W. REPELLENTS AND LARVICIDES FOR THE SCREW-WORM AND OTHER FLIES. Jour. Econ. Ent. 18: 776-778. 1925.

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For the purposes of these investigations a shed was erected in which the jars containing the substances tested could be exposed in fixed positions. This arrangement afforded a more convenient and accurate means of studying fly behavior than when the jars were placed on the ground or on posts or fences and interchanged in position after each observation.

BAITS

In the tests made prior to 1926 of the repellent properties of certain materials too few flies visited the site of the experiments to make the results of certain value. It was therefore thought advisable to make a careful study of the factors affecting the attractiveness of bait (kind of bait, kind of bait container, method of exposing the bait, etc.) so that more accurate and uniform results could be used in comparing untreated bait with bait treated with a repellent. These factors are discussed separately under appropriate headings.

BEEF LIVER COMPARED WITH RABBIT MEAT AS BLOWFLY BAIT

For the purpose of comparing the attractiveness of beef liver and rabbit meat as blowfly bait, six wide-mouth pint Mason jars were baited with fresh beef liver and another six were baited with fresh rabbit meat. The jars were exposed in the shed at Uvalde during May 27 and 28. The weather was fair and warm. A comparison of these two baits was also made at the same time in four jars placed in boxes mounted on posts, and open on one, two, and three sides, respectively. Observations were made at definite intervals of time, and the flies of each species within the jars at each observation were counted. The results are shown in Table 1.

TABLE 1.—*Number of flies per jar baited with fresh beef liver or rabbit meat and exposed under different conditions; Uvalde, Tex., May 27 and 28, 1926*

Species of fly	Kind of bait	Average number of flies in jars in shed	Number of flies in jars in box open on—		
			1 side	2 sides	3 sides
Cochliomyia macellaria	Beef liver	50.8	22	49	39
Do	Rabbit meat	37.5	1	33	16
Lucilia sp	Beef liver	42	20	14	18
Do	Rabbit meat	47.7	21	27	13

These results indicate (1) that rabbit meat has no advantage over fresh beef liver as a blowfly bait, and (2) that more flies were observed per jar in the shed than in the boxes.

RELATIVE ATTRACTIVENESS TO BLOWFLIES OF BAITS OF DIFFERENT SIZES

A test was made at Uvalde on August 4 and 5 to determine the relative attractiveness of chunks of liver of various sizes. Pieces of fresh beef liver of three different weights were placed in ordinary pint Mason jars and exposed in the shed for two days in fixed positions. In this test 12 jars were used, each series of 4 jars containing bait weighing respectively 4, 6, and 8 ounces. The results are shown in Table 2.

TABLE 2.—*Total number of flies of various species observed during two days in three series of four jars, each series containing pieces of a definite weight of fresh beef liver; Uvalde, Tex., August 4 and 5, 1926*

Weight of pieces of bait	Cochliomyia macellaria	Musca domestica	Lucilia sp.	Sarcophaga	Muscina stabulans
4 ounces	140	15	37	19	0
6 ounces	135	13	73	21	2
8 ounces	109	9	31	34	1

The results indicate that increasing the weight of the bait above 4 ounces does not increase the number of screw-worm flies coming to the jars.

RELATIVE ATTRACTIVENESS TO BLOWFLIES OF FRESH BEEF LIVER, CHILLED BEEF LIVER, AND HOG LIVER

A test to determine the relative attractiveness of beef liver in various conditions (fresh and chilled, ground, and in chunks) and hog liver was made at Dallas, Tex., July 7 to 10. Five jars of each of the baits described in Table 3 were exposed in the shed at a packing plant, and were interchanged in position at the end of each observation so as to equalize the conditions of shade and sunlight and other environmental factors as much as possible. Four ounces of bait was used in each jar.

TABLE 3.—*Total number of each of three species of flies observed visiting five jars of each bait during four days' exposure; Dallas, Tex., July 7–10, 1926*

Baits	Cochliomyia macellaria	Lucilia sp.	Musca domestica
Beef liver held in refrigerator 11 days; chunks	1,022	349	367
Hog liver held in refrigerator 1 day; chunks	1,016	462	608
Fresh beef liver; chunks	517	283	494
Beef liver held in refrigerator 8 days; chunks	98	273	344
Beef liver held in refrigerator 5 days; chunks	71	131	87
Beef liver held in refrigerator 3 days; ground	15	93	23

This test indicates that beef liver is more attractive to blowflies when in chunks than when ground in a meat grinder. As no consistent relation between the time beef liver has been kept in a refrigerator and its attractiveness to flies is shown by this test, it seems satisfactory to use fresh liver as a bait in chemotropic experiments. This test also indicates that hog liver and beef liver have about the same attractiveness for flies. No satisfactory explanation is apparent for the wide range in the number of flies attracted to the different baits cut in chunks. This may be due to the kind of organisms of decay which predominated in the different baits.

RELATIVE ATTRACTIVENESS TO BLOWFLIES OF DIFFERENT PARTS OF BEEF AND HOG LIVER

A test to determine the relative attractiveness of different parts of liver was made at Dallas, Tex., July 27 and 28. The results are shown in Table 4.

TABLE 4.—*Total number of each of four species of flies observed in jars each containing a different part of beef and hog liver; Dallas, Tex., July 27 and 28, 1926*

(The liver was cut in 4-ounce chunks and exposed in ordinary Mason jars (1-quart size) for five days)

Kind of liver	Part of liver	Cochliomyia macellaria	Musca domestica	Lucilia sp.	Piophila casei
Dark beef liver, 2 days old	Edge	1,720	904	196	98
Do	Intermediate part	2,240	756	208	136
Do	Center	1,780	776	180	88
Light beef liver, 2 days old	Edge	2,140	1,242	192	144
Do	Intermediate part	2,840	1,076	164	160
Do	Center	2,124	1,056	116	168
Hog liver, 1 day old	Edge	2,656	1,044	216	112
Do	Intermediate part	2,680	916	192	116

These results indicate that there is no significant difference in the attractiveness to flies of different parts of liver. It is advisable, however, to use the same liver in all jars exposed at the same time in a series of tests. Although the hog liver appeared to be the most attractive in this test, too much importance should not be attached to this. There has been observed in various tests a considerable variation in the attractiveness of different liver baits. While the composition of the liver may be one of the causative factors, many other factors are involved, and some of these are not fully understood.

RELATIVE ATTRACTIVENESS TO BLOWFLIES OF THE SAME BAIT IN CONTAINERS OF DIFFERENT TYPES

Four kinds of containers were compared, namely, the ordinary pint Mason jar (diameter of mouth, 2¼ inches; depth, 4⅞ inches), a wide-mouth pint Mason jar (diameter of mouth, 2⅞ inches; depth, 3⅜ inches), a stoneware crock (diameter of mouth, 3⅞ inches; depth, 4⅞ inches), and an enameled pan (diameter at top, 6¾ inches; diameter at bottom, 5¼ inches; depth, 1⅝ inches). The glass jars were colorless, the crocks were a grayish-cream color with a dark-blue band one-half inch wide around the outside 1 inch from the top, and the pans were white on the inside and mottled blue on the outside. One inch of fresh, clean sand covered the bottom of each container, and a 4-ounce piece of fresh beef liver, cut as nearly as possible in the shape of a cube, was used as the bait in each case. The containers were placed in the shed at Uvalde, and observations were made during May 27 and 28. The results are shown in Table 5.

TABLE 5.—*Total number of flies observed during two days in six containers of each type, baited with fresh beef liver; Uvalde, Tex., May 27 and 28, 1926*

Kind of fly	Ordinary Mason jar	Wide-mouth Mason jar	Stoneware crock	Enameled pan
Cochliomyia macellaria	406	305	199	158
Lucilia sp.	232	252	167	161

The results indicate that both species of flies prefer the glass jars to the stoneware crocks or enameled pans, and that the ordinary pint Mason jar (used in previous tests) is as satisfactory a type of container for blowfly bait as any so far tested.

RELATIVE ATTRACTIVENESS TO BLOWFLIES OF BEEF LIVER OF DIFFERENT AGES

Tests to determine the relative attractiveness of beef-liver baits of different ages were made at Uvalde, Tex., June 1–4, when the weather was hot and clear. The liver was cut into 4-ounce cubes, placed in 28 wide-mouth pint Mason jars, and exposed in the shed and in boxes. Seven jars were exposed when the liver was first obtained from a recently killed animal, and seven additional jars were exposed on the second, third, and fourth days of the test. While awaiting exposure the jars containing the liver were kept uncovered in the insectary, where they were inaccessible to insects. The results are shown in Table 6.

TABLE 6.—*Total number of flies observed in 28 jars baited with beef liver of various ages; Uvalde, Tex., June 1–4, 1926*

Species of fly	Age of bait	Day of exposure				
		First	Second	Third	Fourth	Total
Cochliomyia macellaria	Fresh	1	768	2	1	772
Do	1 day old		129	4	0	133
Do	2 days old			153	17	170
Do	3 days old				41	41
Lucilia sp	Fresh	420	112	1	0	533
Do	1 day old		221	58	8	287
Do	2 days old			279	39	318
Do	3 days old				197	197

The results of these tests, as well as those of numerous other experiments, indicate (1) that *Cochliomyia macellaria* flies prefer liver one day old, which is lightly infested with larvæ (the "fresh" bait was infested by Lucilia larvae on the second day, when 768 *C. macellaria* were recorded in that series of jars); (2) that in warm weather there is only a short period during which the liver is strongly attractive to *C. macellaria* flies; (3) that Lucilia flies prefer fresh liver to stale liver; (4) that this positive preference is not so marked as in the case of *C. macellaria* for one-day-old infested liver; (5) that the range of positive response of Lucilia to liver in various stages of decomposition is broader than in the case of *C. macellaria;* and (6) that uninfested liver is more attractive to Lucilia flies than is infested liver.

DISTANCE TO WHICH THE ACTION OF REPELLENTS EXTENDS

Two series of tests were made at Uvalde, June 10–12, to determine how far the action of repellents extends. Fresh beef liver in ordinary pint Mason jars was exposed in the shed at varying distances from meat covered in one case with beta-naphthylethyl ether and in the other with pine-tar oil of 1.065 specific gravity. The treated jars were placed at the intersection of planks crossing each other at right angles and the untreated jars, 16 in each series, were placed at distances of 1, 2, 3½, and 5½ feet, in all four directions from each treated jar. The average number of flies observed in each four jars equidistant from a treated jar is shown in Table 7.

TABLE 7.—*Number of flies observed in each treated jar and average number in each of a series of four untreated jars set at various distances in four directions from the treated jars; Uvalde, Tex., June 10–12, 1926*

Bait (fresh beef liver)	Distance of untreated bait from treated bait	Cochliomyia macellaria	Lucilia sp.	Bait (fresh beef liver)	Distance of untreated bait from treated bait	Cochliomyia macellaria	Lucilia sp.
	Feet				*Feet*		
Treated with beta-naphthylethyl ether		48	9	Treated with pine-tar oil, specific gravity 1.062		52	5
Untreated	1	102	24	Untreated	1	113	23
Do	2	87	20	Do	2	140	19
Do	3½	65	13	Do	3½	128	21
Do	5½	53	14	Do	5½	80	22

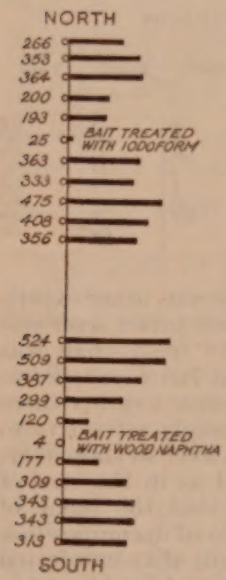

FIG. 1.—Test to determine the distance to which repellents affect flies. The baits were exposed in jars placed at 2-foot intervals along a line running north and south, with a 10-foot interval between the two series. The figures show the number of *Cochliomyia macellaria* observed in each jar

The results of this test are inconclusive. The treated jars show an unusually large catch of flies of both species, which is probably accounted for by the concentration of untreated jars about them. The close grouping of untreated jars toward the center of each of the groups probably also explains the large number of flies in the jars nearest the repellents.

On July 1 and 2 an additional series of tests was made to determine the distance to which repellents are effective, wood naphtha, obtained by the destructive distillation of the wood of the longleaf pine, and iodoform being used as the repellents. All of the jars, 22 in number, were placed in a row running north and south under the west side of the shed and were arranged in two series of 11 jars each, with a space of 10 feet separating the series on the south from that on the north. In each series the jars were placed 2 feet apart, and the center jar was treated with a repellent. Wood naphtha was used in the center jar of the series in the southern end of the shed and iodoform in that of the other series. The results are shown in Figure 1 and Table 8.

It will be noted that there were more flies in the jars toward the center of the shed than in those toward the south end of the wood-naphtha series, and more in those at the south end of the iodoform series than at the north end of the shed. The concentration of odors from the untreated jars toward the middle of the shed and well removed from the treated ones may explain this in part.

TABLE 8.—*Number of flies observed in each treated jar and in each jar of a series of untreated jars set at various distances north and south of the treated ones*

Bait	Distance of untreated bait from treated bait	*Cochliomyia macellaria*				*Lucilia* sp.			
		North	South	Total	Average	North	South	Total	Average
	Feet								
Treated with wood naphtha				4				0	
Untreated	2	120	177	297	148.5	4	5	9	4.5
Do	4	299	309	608	304.0	7	6	13	6.5
Do	6	387	343	730	365.0	3	2	5	2.5
Do	8	509	343	852	426.0	13	6	19	9.5
Do	10	524	313	837	418.5	6	2	8	4.0
Treated with iodoform				25				3	
Untreated	2	193	363	556	278.0	3	4	7	3.5
Do	4	200	333	533	266.5	4	0	4	2.0
Do	6	364	475	839	419.5	7	5	12	6.0
Do	8	353	408	761	380.5	3	3	6	3.0
Do	10	266	456	622	311.0	4	10	14	7.0

These results indicate that a repellent of fairly high vapor pressure (wood naphtha) exerts an action over a radius of 2 feet, while a repellent of low vapor pressure (iodoform) has a somewhat smaller radius of effectiveness. Since the prevailing wind during this test was from the south, it appears that the repellent influence of the iodoform may be responsible for the smaller number of *Cochliomyia macellaria* in the untreated jars 2 and 4 feet north of the treated jar.

EFFICACY OF REPELLENTS

In order to compare the relative efficacy of the repellents determined as most promising by the work of previous years, tests were made with powders and liquids, both in undiluted and diluted form, so as to subject them to as severe a test as possible. The diluted powders were prepared by the addition of kaolin, in the proportions stated for each substance, and the diluted liquids by mixing with refined mineral oil, such as is used medicinally (specific gravity 0.85), in the proportion of 10 cubic centimeters of the repellent to 90 cubic centimeters of the oil. At Uvalde the tests were made in the shed, and the jars were placed 4 feet apart, checks and treated jars alternating. At Dallas the tests were made under a shed at a packing plant, and the jars were interchanged in position at the end of each reading. These tests differ only in that at Uvalde the repellent-treated liver was compared with untreated liver, while at Dallas the repellent-treated liver was compared with liver to which was applied a quantity of the diluent (mineral oil or kaolin) equal to the quantity of the repellent used on the treated baits. Previous tests had shown that the mineral oil used as a diluent was almost neutral in its chemotropic action.

DATA OF THE TESTS

The results obtained in the tests at Uvalde and Dallas are combined in Table 9. The materials are listed in four groups—undiluted powders, diluted powders, undiluted liquids, and diluted liquids. Within each group the materials are presented in the descending order of their ratios of effectiveness as repellents of *Cochliomyia*

macellaria. The percentage ratio (or coefficient) of efficacy is based on the ratio (in terms of per cent) of the number of Cochliomyia flies entering the jars baited with treated meat to the number entering check jars baited with untreated meat. A percentage ratio of 0 indicates perfect repellent action, 100 shows no effect of the material, and more than 100 indicates that the material is attractive to flies.

TABLE 9.—*Results of tests to determine the relative efficacy of various powders and liquids as repellents of blowflies*

Repellent material (used on beef liver)	Cochliomyia macellaria			Lucilia sp.		
	Number of flies		Percentage ratio[1]	Number of flies		Percentage ratio[1]
	Treated jar	Check jar		Treated jar	Check jar	
Undiluted powders:						
Mercuric chloride, 8.65 gm	0	65	0	1	17	6
Copper carbonate, 4.47 gm	0	50	0	0	4	0
Pinene hydrochloride, 5 gm	0	22	0	0	17	0
Cuprous oxide, 9.52 gm	0	18	0	0	7	0
Cupric fluoride, 7.8 gm	0	16	0	0	36	0
Copper carbonate, 2.5 gm	0	11	0	0	8	0
Cuprous chloride, 10.25 gm	0	10	0	0	2	0
Cupric oxide, 9.52 gm	0	7	0			
Cuprous chloride, 9.25 gm	0	5	0	0	1	0
Copper carbonate, 5.7 gm	0	3	0	0	24	0
Copper carbonate, 5 gm	9	929	1	12	32	37
Cuprous sulphide, 17.4 gm	1	67	1	1	61	2
Sodium salicylate, 3.3 gm	1	60	2	15	149	10
Potassium permanganate, 7.15 gm	1	42	2	0	4	0
Yellow antimony sulphide (golden sulphuret), 2.2 gm	3	87	4	3	9	33
Powdered cloves, fresh, 3.25 gm	3	67	4	1	2	50
Cupric sulphide, 13.4 gm	2	26	8	0	24	0
Sodium sulphite, 5.95 gm	8	85	9	1	3	33
Strontium fluoride, 8.2 gm	1	6	17	18	10	180
Kaolin, 2.5 gm	19	94	20	4	9	44
Ferric oxide, 3.4 gm	10	48	21	10	27	37
Naphthalene crystals, 5 gm	212	929	23	3	32	9
Anthracene crystals, 2.5 gm	5	22	23	4	17	24
Animal charcoal, 3.7 gm	25	95	26	5	10	50
Black pepper, 2.7 gm	53	199	27			
α-Naphthylamine, 5 gm	6	22	27	1	17	6
Zinc oxide, 2.7 gm	28	94	30	18	11	164
Black antimony sulphide, 4.7 gm	61	202	30	13	15	87
Kaolin, 5 gm	47	140	34	3	8	38
Barium fluoride, 7.05 gm	47	138	34	9	3	300
Sodium fluoride, 6.32 gm	32	61	52	11	8	138
Magnesium fluoride, 4.65 gm	37	70	53	4	1	400
Precipitated sulphur, 3.3 gm	20	36	56	31	22	141
Precipitated sulphur, 2.5 gm	75	129	58	12	14	86
Sodium benzoate, 2.1 gm	13	16	81	32	32	62
Calcium fluoride, 10.6 gm	77	77	100	2	5	40
Precipitated sulphur, 5 gm	2	2	100	38	35	109
Magnesium oxide, 2.4 gm	69	65	106	16	10	160
Chalk, 2 gm	151	137	110	14	9	156
Calcium sulphide, 4.2 gm	123	101	122	2	12	17
Powders diluted with kaolin:[2]						
Cupric fluoride, 0.78 gm., plus kaolin to make 5 c. c.	0	33	0	1	31	3
Mercuric chloride, 0.086 gm., plus kaolin to make 5 c. c.	0	23	0	0	16	0
Cuprous chloride, 0.92 gm., plus kaolin to make 5 c. c.	0	14	0	0	2	0
Cupric oxide, 0.95 gm., plus kaolin to make 5 c. c.	0	6	0	2	2	100
Copper carbonate, 0.57 gm., plus kaolin to make 5 c. c.	0	5	0	1	51	2
Copper carbonate, 0.5 gm., plus kaolin, 4.5 gm.	3	324	1	6	129	5

[1] Percentage ratio was determined by dividing total number of flies in treated jar by total number in check jar.

[2] "Kaolin to make 5 c. c." signifies that a sufficient quantity of kaolin was added to make a total of 5 c. c. About 4 grams of kaolin was the average quantity required.

TABLE 9.—*Results of tests to determine the relative efficacy of various powders and liquids as repellents of blowflies*—Continued

Repellent material (used on beef liver)	Cochliomyia macellaria			Lucilia sp.		
	Number of flies		Percentage ratio	Number of flies		Percentage ratio
	Treated jar	Check jar		Treated jar	Check jar	
Powders diluted with kaolin—Continued.						
Mercuric chloride, 0.86 gm., plus kaolin to make 5 c. c.	1	80	1	0	16	0
Cuprous sulphide, 1.74 gm., plus kaolin to make 5 c. c.	1	64	2	10	20	50
Cupric sulphide, 1.34 gm., plus kaolin to make 5 c. c.	3	52	6	4	60	7
Cuprous oxide, 1.4 gm., plus kaolin to make 5 c. c.	1	17	6	0	1	0
Pyrethrum powder, 0.5 gm., plus kaolin, 4.5 gm.	14	231	6	78	220	35
Cuprous chloride, 1.06 gm., plus kaolin to make 5 c. c.	1	11	9	0	2	0
Powdered fresh cloves, 0.5 gm., plus kaolin, 4.5 gm.	9	87	10	51	105	49
Iodoform, 0.5 gm., plus kaolin, 4.5 gm.	37	319	12	10	181	6
Barium fluoride, 0.7 gm., plus kaolin to make 5 c. c.	19	121	16	0	3	0
Calcium fluoride, 1.06 gm., plus kaolin to make 5 c. c.	23	132	17	1	4	25
Pinene hydrochloride, 0.5 gm., plus kaolin, 4.5 gm.	55	270	20	43	121	36
Chloroacetophenone, 0.5 gm., plus kaolin, 4.5 gm.	57	260	22	26	119	22
Precipitated sulphur, 0.33 gm., plus kaolin to make 5 c. c.	14	38	37	11	10	110
Sodium fluoride, 0.63 gm., plus kaolin to make 5 c. c.	15	37	41	10	11	91
Sodium benzoate, 0.21 gm., plus kaolin to make 5 c. c.	13	32	41	32	26	123
Hexachloroethane, 0.5 gm., plus kaolin, 4.5 gm.	145	329	44	11	121	9
Magnesium fluoride, 0.46 gm., plus kaolin to make 5 c. c.	38	85	45	18	2	900
Ground black pepper, 0.27 gm., plus kaolin to make 5 c. c.	55	101	54	4	0	∞
Strontium fluoride, 0.82 gm., plus kaolin to make 5 c. c.	4	7	57	21	34	62
Naphthalene, 0.5 gm., plus kaolin, 4.5 gm.	133	232	57	137	113	121
Derris powder, 0.5 gm., plus kaolin, 4.5 gm.	216	350	62	25	129	19
Potassium permanganate, 0.71 gm., plus kaolin to make 5 c. c.	47	66	71	6	4	150
Sodium salicylate, 0.33 gm., plus kaolin to make 5 c. c.	43	49	88	47	100	47
Powdered old cloves, 0.5 gm., plus kaolin, 4.5 gm.	122	99	123	4	9	44
Precipitated sulphur, 0.5 gm., plus kaolin, 4.5 gm.	2	0	∞	19	36	53
Undiluted liquids:						
Cassia oil, redistilled, 5 c. c.	0	22	0	0	16	0
Guaiacol, 5 c. c.	0	22	0	2	17	12
n-Butyl acetate, 5 c. c.	0	22	0	16	17	94
Pine-tar oil sp. gr. 1.055, 5 c. c.	10	951	1	23	49	47
Pine oil No. 4, 5 c. c.	1	53	2	2	9	22
Benzyl bromide, 2 c. c.	2	22	9	12	17	71
Pine-tar oil, pure steam distilled, 5 c. c.	9	66	14	2	34	9
Benzyl chloride, 5 c. c.	12	22	55	18	17	106
2-Bromoethyl acetate, 5 c. c.	13	22	59	11	17	65
Mineral oil, 5 c. c.	354	312	113	27	18	150
Liquids diluted with oil (0.5 c. c. of repellent, plus 4.5 c. c. of oil in each jar):						
Wood naphtha	26	290	9	201	397	51
Pine oil (No. 4) light, destructive distillation	240	1,635	15	108	278	61
Pine oil, pure steam distilled	13	54	24	9	18	50
Crude turpentine	75	285	26	64	251	25
Clove oil	422	1,569	26	185	388	48
Chloropicrin	589	1,822	33	89	410	22
Pine-tar oil (sp. gr. 1.065)	553	1,566	35	118	265	45
Pine tar, medium	59	160	37	126	251	50
Cade oil	519	1,366	38	24	30	80
Spearmint oil	576	1,366	42	27	30	90

TABLE 9.—*Results of tests to determine the relative efficacy of various powders and liquids as repellents of blowflies*—Continued

Repellent material (used on beef liver)	Cochliomyia macellaria			Lucilia sp.		
	Number of flies		Percentage ratio	Number of flies		Percentage ratio
	Treated jar	Check jar		Treated jar	Check jar	
Liquids diluted with oil—Continued.						
Cinnamon oil	156	355	44	108	222	49
Nutmeg oil	166	352	47	158	222	71
Furfural	697	1,366	51	46	30	153
Fennel oil	211	404	52	200	304	66
Citronella oil	259	455	57	191	307	62
Anise oil	787	1,360	58	16	30	53
Pyridine	192	312	62	206	373	71
Guaiacol	841	1,366	62	30	30	167
Pennyroyal oil	161	190	85	74	238	31
Oil of camphor by product	892	1,366	65	34	30	113
Cassia oil, redistilled	109	154	71	126	243	51
Safrol	907	1,366	73	29	30	97
Rose geranium oil	290	375	77	67	225	30
Beta-Naphthylethyl ether	1,066	1,366	78	21	30	70
Coriander oil	1,278	1,366	94	29	30	97
Bergamot oil	565	293	193	47	255	36

DISCUSSION OF THE RESULTS

A study of the results in Table 9 shows that among the undiluted powders the most effective fly repellents are the copper compounds and such strong antiseptics as mercuric chloride, potassium permanganate, and sodium salicylate. The weaker antiseptics, such as the fluorides, sodium sulphite, and sodium benzoate, exert much less repellent action. Inert powders, such as chalk and precipitated sulphur, repel 50 per cent or less of the flies at best. Animal charcoal, which has strong absorbing properties, repels about three-fourths of the flies. Kaolin repels from one-half to three-fourths of the flies.

Certain compounds, particularly calcium sulphide, seem to increase the attractiveness of beef liver to blowflies. Calcium sulphide in the jars gave off a perceptible odor of hydrogen sulphide, and this, being a normal decomposition product of meats, might be expected to be attractive to meat-breeding flies.

Of the powders diluted with kaolin, the copper compounds were the best repellents. Mercuric chloride was still strongly repellent when diluted, and so was pyrethrum powder.

The fact that copper compounds were more effective in repelling blowflies from meat than such strongly odorous materials as chloroacetophenone, cloves, pepper, iodoform, naphthalene, and hexachloroethane is quite remarkable. The repellent properties of the copper compounds must be due largely to their ability to check or change the normal decompositions of meat in such a way that the new products of decomposition evolved are not attractive to flies.

The insect-repellent property of various copper compounds has been noted from time to time by investigators. Brinley [3] sprayed a number of compounds upon bean plants to determine whether they would act as stomach poisons to the tent caterpillar (*Malacosoma americana* Fab.). He writes:

[3] BRINLEY, F. J. INSECTICIDAL VALUE OF CERTAIN WAR CHEMICALS AS TESTED ON THE TENT CATERPILLAR. Jour. Agr. Research 33: 177–182. 1926.

Copper acetate and copper resinate, although contributing nominal control, seemed to have a decidedly repellent effect upon the insect. It required from 6 to 10 days for the caterpillars to consume the foliage given them, whereas the control insects consumed the same amount of foliage in from 1 to 3 days.

In Brudey's opinion, "many of the insects * * * did not die from poisoning but died from starvation because they would not eat the sprayed foliage."

For sheep infested with maggots of the black blowfly (*Phormia regina* Meig.) Mote[4] recommends rubbing the infested area with a crystal of copper sulphate, after shearing the infested wool and removing and killing the maggots. Mote says:

The Ohio station has found the copper sulphate treatment very effective if used in the early stages of the infestation. It dries the infested area and stops the decomposition which gives rise to the putrid smell that attracts the flies. Reinfestation is thus prevented.

Of the liquids mixed with oil, the pine products (wood naphtha, pine tar, pine tar oil, pine oil, and turpentine) show the greatest repellent value. Some of the essential oils (e. g., coriander oil and bergamot oil) become neutral or even attractive when diluted. Some of the materials which showed promise when undiluted (pyridine, furfural, beta-naphthylethyl ether, and others) lose the greater part of their repellent action when mixed with mineral oil. Since the mineral oil used as a diluent was almost exactly neutral in its chemotropic action, these tests indicate that these materials in low concentration have very little effect in repelling flies. They would not be very satisfactory, therefore, for application upon wounds on animals, where evaporation and the licking and rubbing of the wound by the animal would soon reduce the quantity of material below the point where it would be an effective repellent.

The best repellents for flies developed to the present time as the result of this investigation may be classified in the following groups:

1. Products obtained by the destructive distillation of the long-leaf pine (*Pinus palustris*)—pine tar, pine-tar oil, pine oil, and wood naphtha.

2. Pyrethrum powder.

3. Strong inorganic antiseptics—mercuric chloride and copper compounds.

Of these, the pine tar, pine oil, turpentine, and wood naphtha are somewhat irritating to animal tissue to which they are applied, and mercuric chloride is very poisonous to animals. This leaves as the most promising repellents for blowflies, pine-tar oil (the use of which is being taken up extensively by ranchmen), pyrethrum powder, and the copper compounds. Preliminary tests with the last two materials on screw-worm infested animals indicate that they will not prove of practical value.

Experiments are now being made to test the value of powders as practical fly repellents upon cattle, sheep, goats, and other animals under range conditions.

HOW REPELLENTS MAY ACT ON BLOWFLIES

It is obvious that any discussion of the manner in which repellents act on flies must be largely speculative in view of our lack of knowledge of insect physiology and of the chemical nature of many of the materials that are attractive or repellent to insects.

[4] Mote, D. C. [Title illegible.] Ohio Agr. Exper. Sta. Bul. 382, p. 317-318. 1924.

What is spoken of as the repellent action of a material may be due (1) to a true irritant or distasteful effect on the insect which drives it away or (2) to a deodorization of material which is normally attractive to the insect, either as a source of food or for the purpose of oviposition.

IRRITANT EFFECT ON INSECTS

It is probable that some of the compounds used during the Great War as lachrymators, such as chloropicrin, chloroacetophenone, benzyl bromide, and betachlorethyl acetate, have an irritating effect on insects, similar to their action on the eyes and mucous membranes of higher animals. It is also possible that some of the essential oils and other materials (especially aldehydes), when used undiluted, have a true irritant action on insects. The objection to the direct irritants (if the materials mentioned are such) as fly repellents is that with diminishing concentration they lose their effect and in very low concentration may, in fact, become actually attractive. For use under practical conditions such materials must be diluted considerably.

DEODORIZATION OF MATERIALS

Under the second classification of repellent materials are found substances that may act in different ways. It is possible to nullify the attractiveness of a material (e. g., meat) normally attractive to flies by (1) absorbing, (2) adsorbing, or (3) chemically altering the odorous compounds given off, (4) masking their odor with another odor, or (5) inhibiting the formation of attractive odors in the first place.

ABSORPTION OF ODORS

The ready solubility of odorous materials in oils and fats is well known. For example, butter quickly takes up the odor of onions, cheese, or fish. When certain liquids are smeared over meat it is probable that a part, at least, of their action in repelling flies is due to their absorbing the volatile odorous principles normally attractive to flies.

ADSORPTION OF ODORS

Kaolin, charcoal, and other powders have the property of adsorbing or condensing vapors on their surfaces. The moderate repellent effect of animal charcoal when spread over meat is very likely due to this property.

CHEMICAL NEUTRALIZATION, OXIDATION, OR REDUCTION OF ODOROUS COMPOUNDS

The odor of ammonia can be eliminated from a closed space by introducing therein an equivalent quantity of hydrochloric acid, which forms the inodorous ammonium chloride. This is an example of chemical neutralization. None of the materials, however, which have been used in these tests as fly repellents are likely to be of this class.

By means of oxygen (more particularly ozone) or chlorine, malodorous gases may be oxidized to inodorous compounds. The use of chlorine gas in deodorizing the gases formed by the combustion of garbage is well known. Under the conditions of the tests it seems hardly possible that any of the materials oxidized the gases from meat.

By the hydrogeneration of unsaturated compounds their odor is materially lessened or changed. For example, the odor of fish oils is largely eliminated by this process. None of the materials tested, however, could be expected to have a measurable reducing action on the volatile products arising from meat under the conditions of the tests.

It is also possible to deodorize strongly odorous materials by chlorination and other chemical processes, but none of the materials tested would effect such a change.

MASKING OF ODORS

Most deodorization so-called, at least as far as the human sense of smell goes, is accomplished by covering up one odor by another. It may well be, however, that insects are still capable of detecting an odor normally attractive to them irrespective of the presence of another odor which to the human nose is more powerful and completely hides the first odor. The effect produced by essential oils and perfumes comes under this heading.

INHIBITING THE FORMATION OF ODORS

The fact that meat must undergo a certain decomposition before it becomes attractive to flies is strikingly shown by the nonattractiveness of certain specimens of chilled beef liver. The repellent effect of such inodorous materials as mercuric chloride and the copper compounds is undoubtedly due to their ability to inhibit the usual decomposition of the meat, thus preventing its attractiveness to flies. The phenols in pine-tar oil are probably responsible to a large degree for the excellent fly-repellent value of this material.

It is believed that, in the search for practical blowfly repellents for application upon animals, materials which absorb, adsorb, or prevent the formation of volatile compounds attractive to the flies offer more promise than irritating materials (true repellents) or odorous substances designed to mask the odors attractive to flies.

SPECIES OF FLIES OBSERVED IN THE TESTS

The species of flies observed within the jars at both Dallas and Uvalde during the tests in 1926, in their order of abundance, were as follows: *Cochliomyia macellaria* Fab., 38,066; *Musca domestica* L., 9,948; *Lucilia* sp., 8,394; *Piophila casei* L., 1,022; *Sarcophaga* sp., 864; *Phormia regina* Meig., 238; *Ophyra* sp., 91; *Muscina stabulans* Fall., 72; and comparatively few specimens of *Cynomyia* sp., *Calliphora* sp., and *Drosophila* sp. These tests were made at various times from about the first of April until the middle of November.

EFFECT OF WEATHER CONDITIONS AND OTHER FACTORS ON FLIES

Flies are very responsive to changes in temperature, humidity, barometric pressure, wind velocity, solar radiation, and other weather factors. Intensity of light, color, and other factors also affect the reactions of flies. A study of the relations between fly activity and these factors is now being made and will form the subject matter of a separate publication.

SUMMARY

Beef liver, hog liver, and rabbit meat are all attractive to blowflies and are suitable for bait. The age of the meat, and whether it is in chunks or ground, affect its attractiveness to flies, and apparently chilling also has some influence.

The type of container affects the attractiveness of the bait to flies. A transparent container is more attractive than an opaque one.

A study of the methods of exposing bait containers and of the distance over which repellents are effective has led to the development of a method of studying the repellent properties of materials to blowflies which is believed to yield more accurate results than any hitherto recorded. This method of ascertaining the repellent value of a substance consists in smearing 5 cubic centimeters of material upon a 4-ounce cube of fresh beef liver placed on 1 inch of clean, dry sand in an ordinary pint Mason jar, and counting the number of flies within the jar at stated intervals of time. Comparison is made with the number of flies visiting similar jars containing untreated meat and placed 4 feet from either side of the treated jar. Periodic observations are continued as long as flies in numbers continue to visit the untreated meat (from 2 to 4 or 5 days). The percentage ratio of flies visiting the treated jar, compared with the average number visiting the adjacent check jars, in the case of any material studied, expresses the repellent value of the material.

The most promising blowfly repellents found as the result of this investigation are pine-tar oil (now being used on an extensive scale by ranchmen), pyrethrum, and certain copper compounds.

It is believed that the future line of progress in the employment of repellents lies in the use of materials which will absorb, adsorb, chemically alter, or prevent the formation of volatile compounds attractive to the insects rather than in the use of masking odors, such as those of essential oils or of irritants (such as the tear gases).

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